Invited Paper

Status of Optical Disk Standards and Copy Protection Technology

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ABSTRACT

Optical data storage is now well into the second decade of continuing market and technology expansion. Media removability, whish is the main attribute of this technology, presented the optical recording industry with unmatched opportunities and also new challenges. On the one hand, data interchange between the media and drives from different sources becomes a major concern, which can only be solved if international standards for all optical recording disk/cartridge are available. Many standards organizations, with the help of world wide industrial support, took up the challenge, and numerous international standards were established which are now being adapted. One the other hand, copy protection technology must be developed to prevent illegal copying and distribution of contents using this removable media. This need is accentuated by the proliferation of low cost CD and now DVD disks replication means and the availability of recordable and rewritable CD and DVD devices. This paper provides an update of the brief summary of the current status of the international optical disk standards published ealier[1] and a breif review of the copy protection technology.

Keyword: Optical recording, international standards, copy protection

I. INTRODUCTION

Research and development in optical data storage started more than three decades ago. Product introduction however was not realized until early 1980's. Initial devices were mainly read only or write-once-read mostly (WORM) types. The very first attempt to offer a guideline of a WORM disk standard was presented by T. A. Olson [2] at the Optical Data Storage Topical Meeting in 1983. Subsequently, the National Bureau of Standards (now NIST) took on the task to promote optical disks international standards and held numerous meetings on the standards development. Participation of ANSI in developing the optical disk standards started in 1984 and the X3 B11 committee was created. The first B11 Chairman was Mike Deese, who held the first International Standardization Organization (ISO) SC23 meeting in Japan. In the ensuring years, B11 committee was chaired by Joe Zajaeczkowski, Ken Hallam, Pat Sandell and now John Neumann. The B11 committee is now organized under National Committee for Information Technology Standards (NCITS). Concurrently, the European Computer Manufacturers Association (ECMA) added the optical disk standards to their standards activities and formed a Technical Committee TC31 in 1984. These activities are now coordinated by the joint technical committee (JTC1) under joint effort of ISO and the International Electrotechnical Commission (IEC). All industrial nations, with US, Japan and some European countries as the major contributors, joined this effort and resulted in numerous international standards, including read only, WORM, recordable (Dye polymer or ablative media) and rewritable disks, (magneto optic or phase change media) with disk diameters ranging from 80 mm to 356 mm. The most popular read only Compact Disc (CD-ROM), started with a de-facto standard by Philips and Sony, are now also embraced by the international standards. More recently, Digital Versatile Disc (DVD) technology was introduced. The standards work on this type of disks is on Fast Track and the first group of DVD disc standards have been completed.

The ease of copying information to a recordable or rewritable CD or DVD optical disc brought about the need for copy protection. The work was started over four years ago. The three industrial concerns, namely the Information Technology (IT), the Consumer Electronics (CE) and the Content Providers such as the Motion Picture Association (MPA) and Secure Digital Music Initiative (SDMI), realizing the importance of copy protection, agreed to join force to develop the required

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technology. The work is coordinated under the Copy Protection Technology Working Group (CPT-WG), with Allen Bell of IBM as the Chairman. CPT-WG meets monthly, participated by all industrial concerns, with the support of the DVD Forum WG-9, Mt. Fuji, DVD-CCA, MPA, SDMI, and many other organizations. The technologies developed to date includes the proprietary Content Scrambling System administrated by DVD-CCA, the use of Watermark in the content. More recently, the proprietary Copy Protection techniques for Recordable Media and Prerecorded Media (CPRM and CPPM) were developed which will be available for licensing.

In this paper, we will review the activities of of ISO/IEC JTC1, ANSI, ECMA and other organizations including OSTA, and DVD-Forum. The status of copy protection technologies developed to date will then be discussed.

II. ANSI NCITS B11 STANDARDS ACTIVITIES

The American National Standards Institute started the pioneering effort in optical disk standards and established the X3 B11 (now NCITS B11) committee in 1984. Much of the early work was in the WORM disks using ablative recording media with 300 mm and 130 mm disk diameters. By late 1980 and early 1990. recordable and rewritable disks was introduced. 90 mm, 120 mm (CD) and 130 mm disk sizes standards were advancing rapidly. Test and measurement standards were also introduced. In the mid 1990, DVD discs were developed. DVD-ROM, DVD-recordable and DVD-rewritable disc standards are currently under intense development. The ANSI NCITS B11 activities and accomplishments over the past fifteen years are monumental indeed. This is a tribute to the world wide contributions and cooperation from all national bodies, companies, and individuals in this field.

Over the years, developers of optical recording media and drive have generated a set of important parameters which collectively defines a disk standard. Nearly all disk and cartridge standards, irrespective to the size and usage, have included detailed values and margins of these parameters to insure data interchange. These essential disk parameters are:

(1) Environmental: Operating, transportation and storage
(2) Mechanical and Physical:
(3) Optical:
(4) Reference Drive:
(5) Track Format:
(6) Data Format:
(7) Read /Write/Erase Laser Power and power control
(8) Data Coding: Modulation Code, Error Correction Code
(9) Defect management
(10) Test and measurement:
(11) Annexes: Optional features as permitted

Besides these, there are many variations and additions which may be required for a specific case.

With this many parameters which must be defined in detail for each disk standard, and be agreed by all concerns, the task to establish a standard is indeed overwhelming. From the start of the acceptance of project proposal, going through a number of versions of draft standards for review and comments with letter ballots, and eventually resolving all objections and reach the final publication of an international standard, typically takes years of work. The projects developed under B11 committee and the resulting standards published are summarized in Table I.

As the optical disk standards activities gravitated into the international arena in the past two years, the work under NCITS B11 has now dropped from an active to a maintenance mode.

III. ISO/IEC JTC1 STANDARDS ACTIVITIES

The members of the International Organization of Standardization and International Electrotechnical Commission participate in the development of International Standards through the joint technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations in liaison with ISO and IEC, also take part in the work. ISO/IEC information technology technical committee JTC1 was established to work on the standards in the information industry including the optical disks. Within JTC1, there are a number of subcommittees (SC) each addressing a specific area of work. Working groups (WG) within the SC are where the most significant work being conducted to address the technical issues, and to resolve differences. All National Bodies (country members of ISO and IEC) can participate in this standards work. Under the standard 5-stage development procedure, any standards project must first be approved, and editor(s) assigned to prepare the working draft international standard (WD). The draft is then reviewed and modified by all National Bodies. The working group is the venue where the National Bodies participate in resolving technical issues. The standards so prepared then go through several letter ballots: Committee Draft (CD) and Final Committee Draft (FCD) at the SC level, and Final Draft International Standard (FDIS) at the JTC1 level. This balloting procedure can be as short as 6 months, or as long as 18 months, depending on the technical maturity of the WD when it is first balloted. At long last, an international standard will be published.. JTC1 has also offered an additional method of producing an International Standard known as the Fast Track procedure. In this case, after the approval of the standards project, and assignment of the editor(s), a draft international standard (DIS)will be prepared. The draft is reviewed and modified by all national bodies and the working groups will participate in resolving technical issues. The standards so prepared will go through one of more letter ballot procedure..

IV. ECMA STANDARDS ACTIVITIES

The European Computer Manufacturers Association (ECMA) was formed in 1961. In 1987, a technical committee TC 97 became part of ISO/IEC JTC1, ECMA became A-liaison member of JTC1, thereby accelerating the process by which ECMA standards can be adapted as an International Standard. Mr. Dora Hekimi held the position of Secretary General from 1961 to 1991. This position is now taken over by Mr. J. van den Beld. The ECMA optical disk/cartridge standards activities are organized under TC 31. From 1987 to 1991, the work has been in the development of 130 mm WORM and R/W disk standards, 90 mm R/W and CD-ROM. From 1992-1996, 90 mm and 130 mm disks of different applications were included, together with SSF and CCS servo methods, and CD and PD format disks. Since 1997, 120mm and 80mm DVD disk standards have been the center of action. The classification of Optical Disk Case/cartridge Standards defined by ECMA and ISO/IEC is summarized in Table II[4].

V. OTHER STANDARDS ACTIVITIES

Much of the ANSI and ECMA standards work are in coordination with the Japanese standards organizations. In fact, much of the recent technical work on optical disk/cartridge was developed in Japan. DVD-Forum, chaired by Koli Hase of Toshiba was founded in 1995 by 10 companies (Hitachi, Matsushita, Mitsubishi, Philips, Pioneer, Sony, Thomson Multimedia, Time Warner, Toshiba and Victor Company of Japan), with purpose of maintanence and development of DVD specifications.. Currently there are 100 members who take part in the Forum activities, promoting and developing products based on DVD Specifications, and receive information.. to One of the main contribution of DVD Forum to DVD disc standards is through the publication of DVD books. The DVD books published to date is listed in Table III[3]. There are many verification laboratories established world wide, inlcuding Philips in Europe; Hitachi, JVC, MEI, Pioneer, Sony, and Toshiba in Japan; ITRI in Taiwan, and Warner in US, to serve as the clearing house for disc or drive conformation to the standards set by the books.

With respect to rewritable DVD discs, there is the Mount Fuji working group which deals with all aspects of the issues related to Content Protection, Real Time recording, and Access Control. On audio recording, Secure Digital Music Initiative (SDMI) is leading the effort.

Besides these organizations, a world wide trade association named OSTA (Optical Storage Technology Association) was organized by Ray Freeman in 1992, consisting of members from optical product manufacturers from three continents. The purpose is to promote the use of writeable optical technologies and products for storage of computer data and images. In the past, OSTA has been working on the migration path for the 130 mm and 90 mm writeable drives, to insure that technology advances will not cause premature obsolicence. More recently, OSTA has been working on the Universal Data Format (UDF), and compatibility issues for CD and DVD discs. A MutiRead technology was advanced which defined the requirements for the readablility of CD-ROM, CD-R and CD-RW discs by all CD devices. This technology is being extended for DVD drives.

There are many other standards activities world wide which will have an direct impact to Optical Disk standards. The data format such as UDF as mentioned above, and the Multi Media Command Set Standards proposal under NCITS T10 for example, can directly affect the ability for data interchange of optical disks. These activities should be taken into consideration carefully in the development of disk/drives comforming to the specified International Standards.

VI. COPY PROTECTION TECHNOLOGY

In the US, there is a concerted effort to address the Content Protection Technology. The future market development in DVD recordable technology depends on the availability of acceptable Content Protection standards. Development of the technologies for the protection of intellectual properties has been in progress since the mid 1990's. This effort involves many complex issues such as the technology development, the legal reminification, the business interests, and the consumer acceptance. To be acceptable to all concerns, this work has a goal to prevent illegal copying of contents, to be invisible to users, to be compatible to existing architecture, to require minimum management, to be low cost, to encourage voluntary compliant, to be robust and to allow technology growth.

There are many organizations currently involved in the development and administration of the copy protection technologies. The Copy Protection Technology Working Group (CPT-WG) is the coordinating orgainzation which ia working with the Information Technology Inductry Association (ITI), the Content Providers such as the Motion Picture Association of America (MPAA) and the Recording Industry Association of America (RIAA), and the Consumer Electronic Manufacturers Association (CEMA) together to develop the required technology.. There is a monthly meeting to review progresses and resolve issues. The DVD Forum has the WG-9 working group to addresses the DVD copy protection in total systems. The Technical Working Groups such as the ad hoc group AhO-3 within TC-31 which deals with the DVD-R devices. To address the copy protection as data is transmitted, there is the Data Transmission Group which deals with protection in the data interface. For the read only media such as DVD-ROM, a proprietory Content Scrambling System (CSS) has been developed. This system is now implemented and available for licensing through DVD-CCA. An earlier version of CSS unfortunately was broken by a hacker late last year, resulting in much legal and technological debate. The other technique is the use of Water Mark which is embedded in the content and provides a way for tracking and control of the stored information. This system is however still under development and not yet implemented for a number of reasons. One is related the selection of the two proposed Water Mark techniques namely the Millennium system and the Galaxy system. Decision has yet to be made as to which one to use. Also there has been much debates on the location where the Water Mark detection should take place. It could reside in the drive or in the data processing system.

IBM, Intel, Toshiba and Matsushita (4C) have advance a general guide line of the architectural aspects of copy protection, (copy protection systems achitectural CPSA). 4C also introduced copy protection techniques in two proposals, one for recordable media (CPRM) and one for prerecorded media (CPPM). The system is based on three technical elements: (1) Key management for interchangable media, (2) Content encryption and (3) Media Based renewability. Deteail of these proposal can be accessed through 4C web site[5]. These proposals are currently under discussion and the technologies are expected to be available for licensing in the near future.

The above mentioned technologies are media and drive related. There is also some interest to develop copy protection in the data transmission between PC (video traqnsmission) and the display device (video receiver). A Digital Visual Interface

(DVI) specification has been proposed by Intel, in corporation with Silicon Image. Information may be obtained from DVI web site[6].

Copy Protection technology is still at the stage of rapid development. It appears that all currently available techniques are privately developed and details are not in the public domain. However, for the protection of content providers, disc and drive manufacturers are urged to participate and endorse the copy protection technologies, for the benefit and health of the entire industry.

VII. CONCLUSION

The creation of the international standards of optical data storage disks and cartridges is a major endeavor of this industry.. Earlier effort, with the exception of CD, was initiated in the US. Earlier US participants includes major companies such as 3M, DEC, IBM, Kodak, HP, Verbatim, and start-up companies such as ISI, MaxOptix, and Optotech. The critical parameters and other pioneering work for optical disk standards were developed during this period. By 1990's, the effort in the development of optical data storage devices and media in US decreases drastically. Associated with the reduced US drive and media industrial participation, the standards work started to migrated from US to Europe and Japan. At present, ANSI NCITS B11 committee has reduced its work from the active to a maintenance mode. ECMA is now leading the optical disk standards activities, and many of the hard technology and engineering work in standards are being carried out in Japan. For the DVD disc standards work, major companies in Japan, such as Hitachi, MCC, Matsushita, Pioneer, Ricoh, Sony, Toshiba, Yamaha, together with Philips in Europe, and HP in US, are now the main driving forces.

As the optical recording technology advances, the optical standards activities will continue to expand. Although it is important to encourage new development, we must not loss sight in the ability to recover information stored in optical disks. Studies have shown that most optical disks will have a data retention life of over 50 years. The main concern is whether there will be a drive which can recover the data stored on the disk at that time. This may be the ultimate test of Data Interchange that we should be addressing.

The ease of record data on optical disks brought about a concern for copy protection. The Information Industry, the Content Provider and the Consumer Electronics Industry are joining force to develop user friendly, low cost solution to the copy protection technology. Many approaches advanced to date are either being implemented or will be implemented in the near future. It is however important to realize that any protection technology are susceptible to tempering, and in time could be broken. Any copy protection technology must establish a clear path for migration to higher level of protection as the need arises. This may be the best strategy to insure a long term solution for this complex problem

ACKNOWLEDGMENTS

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6. DVI web site: www.digital-cp.com.

Table I. Summary of the Status of Projects Under NCITS B11 Committee:

Project	Disk Dia. (mm)	Read only	Worm	MO	PC	Servo	Cap. (MB)	Publication	Yr Pub.	Note
408-L	300		X			SSF		ISO 13614	95	
483-L	300		X			CCS		ISO 13403	95	
480-L	120	X					650	ISO 10149	89	CD-ROM
456-M	356		X					ISO 10885	93	
457-M	130		X			CCS	325/s	X3 211	92	Unrecorded
481-M	130		X			CCS	325/s	X3 211	92	Recordable
659-M	130		X			SSF	325/s	X3 214	92	4/15 mod.
655-M	130		X			Di-bit	650/s	X3 191	91	RZ modulation
607-M	130			X		CCS	325/s	X3 212	92	
736-L	86			X		CCS	128	ISO 10090		
760-M	86			X		DBF	113	X3 214	94	
679-M	356		X					X3 191	91	Test method
879-M	130		X	X		CCS		ISO 10089		CCW Tech.
883-D	90					CCS				Test method
884-M	130					CCS		X3 234	93	Test Method
893-M	130			X		CSS	2000	ISO 13842	95	MCAV
915-M	90			X				ISO 15041		Extended Cap
950-M	90					CCS		X3 244	95	Test Method
953-M	90					DBF		X3 246	94	Test Method
985-D	130				X		2000	B11 94/154	94	
1000-L	130			X			1000	ISO 13481	93	
1001-L	130			X			1300	ISO 13549	93	
1004-M	130			X			2600	ISO 14517		
1029-D	356				X			DIS 15882		

Project	Disk Dia. (mm)	Read only	Worm	MO	PC	Servo	Cap. (MB)	Publication	Yr Pub	Note
763/4-L								ISO 13364	95	Rewritable VF
1055-L								ISO 13800	95	Vol. File Stru.
1066-L	130		X					TR 10091	95	Tech. Aspects
1068-L	90									Measurement
1158-M	90				X		1300	ISO 14760		
1159-I	130	X		X			5200	DIS 15286	99	
1184-M	90				X		230	ISO 13963	95	
1188-L	120	X	X							Vol. File Stru.
1189-L	86			X		CCS	128	TR-13561	94	Tech. Guide
1322-L	120	X						TR 18002	99	DVD File TR3
1323-L	120				X		650	ISO 15485	97	PD format
1324-L	120	X					4700	DIS 16448	99	DVD-ROM
1325-L	120				X		2600-5200	DIS 16824	99	DVD-RAM disk
1326-L	120							DIS-16825	99	DVD-RAM case
1327-L	120				X		3000-6000	DIS 16969	99	+RW format
1328-L	80	X						DIS 16448	99	DVD-ROM
1329-L	90						650	IS 15498	97	HS-1 format
1330-L	130		X	X			2600	IS 15486	99	CCW Tech.

Table II. Classification of Optical Disk and Case/Cartridge Standards (After ECMA) [3]

Size in mm	Maximum Capacity	ECMA Standard	ISO/IEC Standard	Recording Technology		Media Types				
				MO	PC	R/W	WORM	WO	P-ROM	O-ROM
80	5,3 Gbytes **	ECMA-268	ISO/IEC 16449							DVD-ROM
90	128 Mbytes	ECMA-154	ISO/IEC 10090	X		X		X	X	X
90	230 Mbytes	ECMA-201	ISO/IEC 13963	X		X			X	X
90	385 Mbytes	ECMA-223	none	X		X				
90	640 Mbytes	none	ISO/IEC 15041	X		X			X	X
90	650 Mbytes	ECMA-239	ISO/IEC 15498	X		X			X	X
90	1,3 Gbytes	none	ISO/IEC 14760			X			X	X
120	660 Mbytes	ECMA-130	ISO/IEC 10149							CD-ROM
120	650 Mbytes	ECMA-240	ISO/IEC 15485			X	X			
120	17.0 Gbytes **	ECMA-267	ISO/IEC 16448							
120	5,2 Gbytes	ECMA-272	ISO/IEC 16824			DVD-ROM				
120	Case	ECMA-273	ISO/IEC 16825							Case
120	6.0 Gbytes	ECMA-274	ISO/IEC 16969			+RW				
130	650 Mbytes	none	9171				X			
130	650 Mbytes	none	ISO/IEC 10089	X		X				
130	650 Mbytes	ECMA-153	ISO/IEC 11560	X				X		
130	1 Gbyte	ECMA-183	ISO/IEC 13481	X		X		X		
130	1.3 Gbytes	ECMA-184	ISO/IEC 13549	X		X		X	X	X
130	2 Gbytes	ECMA-195	ISO/IEC 13842	X		X		X	X	X
130	2.6 Gbytes	none	ISO/IEC 14517			X		X	X	X
130	2.6 Gbytes	ECMA-238	ISO/IEC 15486	X			X			
130	5.2 Gbytes*	none	CD 15286	X		X		X	X	X
300	12 Gbytes	ECMA-189	ISO/IEC 13614				X			
300	12 Gbytes	ECMA-190	ISO/IEC 13403				X			
356	6.8 Gbytes	none	ISO/IEC 10885				X			
356	14.8 & 25 Gbytes	ECMA-260	ISO/IEC 15898				X			

Legend

X specified in the standard, * Double sided, ** Double sided, double layered

none no ECMA or ISO/IEC standard in existence for this ODC

Table III. DVD Book Construction (after DVD-Forum)[4]

Book Name	DVD Specification	Version
DVD-ROM Part 1	Physical Specifications	1.0_2
DVD-ROM Part 2	File System Specifications	1.0_2
DVD-Video Part 3	Video Specifications	1.1_1
DVD-Video Part 3	Reference Information-JacketPicture Format	1.0_1
DVD-Video Part 3	Reference Information-IEC958 to convey non-PCM encoded Audio bitstream	1.0_1
DVD-Audio Part 4	Audio Specifications	1.1
DVD-Audio Part 4	Reference Information-Packed PCM: MLP Reference Information	1.0
DVD-R (3.9 G) Part 1	Physical Specifications	1.0
DVD-R (3.9 G) Part 2	File System Specifications	1.0
DVD-R for General (4.7 G) Part 1	Physical Specifications	1.95
DVD-R for General (4.7 G) Part 2	File System Specifications	to be issued
DVD-R for Authoring Part 1	Physical Specifications	2.0
DVD-R for Authoring Part 2	File System Specifications	1.9
DVD-RAM (2.6G) Part 1	Physical Specifications	1.0
DVD-RAM (2.6G) Part 2	File System Specifications	1.0
DVD-RAM (4.7G) Part 1	Physical Specifications	2.1
DVD-RAM (4.7G) Part 2	File System Specifications	2.0
DVD-RW Part 1	Physical Specifications	1.0
DVD-RW Part 2	File System Specifications	1.0
DVD-Video Recording Part 3	Video Recording	1.1